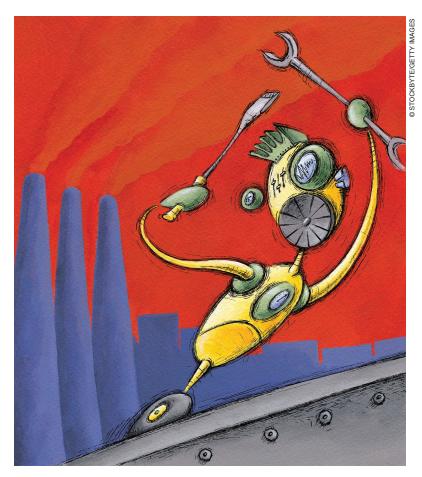# Talkin' 'Bout a (Nanotechnological) Revolution

ROBERT SPARROW

It is often claimed that the development of nano-technology will constitute a "technological revolution" with profound social, economic, and political consequences. The implications of this claim can be illustrated by a scenario in which a political revolutionary made the same claims that are commonly made by enthusiasts for nanotechnology. Most people would be outraged to learn that the members of an unelected group were planning to radically reshape society in this fashion. I survey arguments that might be used to block this analogy and argue that none of them justify drawing a sharp distinction between social change due to technology and change due to other political causes. Two things follow from this discussion: First, we need to reconsider the appropriateness of the language of technological revolution when talking about nanotechnology. The likely impacts of nanotechnology may be less dramatic than is often claimed. Second, if we do decide that the language of revolution is appropriate for nanotechnology, then we should acknowledge that any such revolution should be delayed until the public can make a democratic decision about whether they wish their lives to be transformed in this way.

Nanotechnology Revolution

Nanotechnology, the science of developing tools and machines as small as one molecule, will have as big an impact on our lives as transistors and chips did in the past 40 years. Imagine highly specialized machines you

ingest, systems for security smaller than a piece of dust and collectively intelligent household appliances and cars. The implications for defense, public safety and health are astounding.

Newt Gingrich, former Speaker of the U.S. House of Representatives [24]

The next Industrial Revolution is right around the corner. Fourth generation nanotechnology — molecular manufacturing — will radically transform the world, and the people, of the early 21st century.

Center for Responsible Nanotechnology [9]

Barring worldwide destruction or worldwide controls, the technology race will continue whether we wish it or not. And as advances in computer-aided design speed the development of molecular tools, the advance toward assemblers will quicken.… They promise to bring changes as profound as the industrial revolution, antibiotics, and nuclear weapons all rolled up in one massive breakthrough.

K.E. Drexler [14]

Imagine that you come home one night and turn on the television to relax in front of your favorite talk-show. The host is interviewing a bearded man you don't recognize and whose name you have never heard before. The topic of the interview catches your attention though: This mysterious bearded figure is announcing a revolution!

This revolution will, he says, "change the world" ([3], [5], [6, pp. 1-47], [12], [14]-[16], [29]-[33], [40], [42], [45], [46], [48], [49], [61], [69].[1] It will be a global

revolution, respecting no national boundaries ([14], [32], [66]). It will totally change social relations, fundamentally altering the way we live. It will provide wealth for all ([12], [14]- [16]). It will feed the poor and bring succour to the sick [12]. It will heal the planet, restoring the natural environment and providing clean drinking water and energy for remote communities ([11], [34], [38, pp. 5-7], [52], [53], [60]). It will even improve human nature, making people both smarter and longer-lived ([12], [40], [47]). His enthusiasm is contagious— although you also notice that he is a little short on specifics as to how this revolution will achieve these things.

When pressed, he admits that there will in fact be winners and losers in this revolution. It is likely that it will lead to severe social disruption, including the closure of some industries, putting tens of thousands of people out of work ([2, pp. 37-38], [9], [11], [13], [38], [41], [70, p. 42]). He assures viewers that these people will be appropriately compensated and will be "better off in the end." However, he continues — and here his voice becomes grave — it would be irresponsible of him to guarantee that no lives will be lost. Some people may die as mistakes are made on the road to progress. You can't make an omelette without breaking eggs.

The TV host suggests that it would be better to proceed cautiously rather than advance headlong, putting lives at risk. Perhaps we should not proceed until we know that the plans for a bloodless transfer of power are secure.

[1]Sources provided for the claims made in italics in this "hypothetical" refer to contributions to debates about nanotechnology or about science and engineering more generally which contain the claims paraphrased and/or parodied in the hypothetical. Where the claims made by the "revolutionary" are mild parodies of claims made in the debate about nanotechnology, the reference is intended to demonstrate that the caricature is nevertheless an accurate one.

The revolutionary guffaws. "If people had waited until revolution was safe, we would never have had any revolutions. We must trust in our judgement that our cause is just" ([8], [26], [62]). As he says this, you realize that he has a slight American accent.

The host demands to know more about this group of revolutionaries: Who are they? Where do they come from? Are they elected?

At this point the revolutionary shifts in his chair. "Unfortunately, we cannot be elected. The masses are not educated enough to be trusted to make the decisions we must make. Becoming a member of our organization takes years of training" [1].

"But it is open to the public?"

"I am afraid not. The tests for entry are arduous and we are forced to reject many who might wish to be involved."

"So what sort of people are members? Are there as many women as men? Are there ordinary people in your organization?"

The revolutionary looks even more uncomfortable. "Our members are mainly men," he admits. "They are of necessity an elite group" [4], [44].

Eventually, the "revolutionary" is forced to admit that his organization consists largely of professional people drawn from universities and government, and includes many senior executives drawn from some of the largest multinational corporations in the world.

Perhaps the public does not want a revolution, the host suggests, especially one led by such a privileged group.

Her guest is unfazed. The forces of history are, he insists, on his and his fellow revolutionaries' side. Staring earnestly at the camera, he declares "Our revolution is inevitable" ([12, p. 194], [23, pp. 187-188], [39], [42], [64, pp. 12, 188]).

"So what you are saying," suggests the host, "is that a self-selected, elite group, including

representatives of some of the wealthiest and most powerful people on the planet, is planning to fundamentally change the world, without consulting anyone outside of their political movement."

How would you react to such news? I suspect you would be outraged to learn that the members of an unelected group were planning to radically reshape society and would demand that they be stopped. However, a technological revolution is precisely what the public is expected to embrace in the current debate about nanotechnology. The above scenario simply transposes claims about nanotechnology into the political realm. As the sources cited above demonstrate, the claim that nanotechnology heralds a revolution appears in the popular press, scientific journals, government reports, and the remarks of reputable scientists, as well as in the writings of more speculative "nanofuturists" such as Drexler and Crandall.[2] Yet, the demand that any such revolution be stopped, at least until the public has had a chance to make a democratic decision about whether they wish their lives to be transformed in this way, receives scant consideration in most discussions of the future of nanotechnology.

Political vs. Technological Revolution

Why is there such a disjunction between our attitudes towards political and technological revolution? Thinking about this question is a useful exercise when considering how a democratic society should negotiate issues relating to science and technology [68, pp. 99-102] and, in particular, when considering how we should respond to the "nanotechnological revolution."

Perhaps many of us don't worry about the possibility that our lives will be transformed by a revolutionary

new technology, without our consent, is because we take their claims, about technological revolution with a large grain of salt. A genuinely revolutionary technology would fundamentally change the way society is organized and the way people live.[3] Yet, despite all the new technologies developed over the last 40 years, the basic form of human life, at least in industrialized nations, has remained more or less the same. The vast majority of people spend most of their time working for other people. In the industrialized world, they live in houses, work in offices or factories, and commute to work by car or train. Robots do not do our house work. Cancer continues to kill. Poverty, disease, and famine still stalk the Third World. Our society has not become noticeably more rational or democratic. This is not to deny that society has changed as a result of the impact of new technologies. However, it is to insist that these changes have been relatively superficial [18].

I have limited my claim about the superficial nature of the impact of technology to the last 40 years—and to the industrialized nations— deliberately, because the claim that technologies changed the world prior to this period is more plausible. Antiseptics and antibiotics, public health, reliable forms of contraception, railroads, and the internal combustion engine all had an enormous impact on the basic form of human life in the 18th, 19th, and early 20th-century, significantly lengthening the average lifespan, transforming relations between the sexes, and making it possible for the majority of the population to live in cities rather than in the country. Compared to these technologies, the information and biotechnology "revolutions"

have to date had comparatively little impact on social or political relations [18].

This skeptical response to claims about revolutionary technologies rests on the belief that such technologies are unlikely to live up to their name, either because their potential has been over-hyped, or because they will leave the fundamental form of our way of life unchanged [18], [55]. It therefore offers little comfort to those who genuinely believe that nanotechnology will change the world. However, to the extent that we *do* believe that nanotechnology will transform our lives, it seems that we should be equally concerned about who is shaping this transformation.

Government/ Corporate Planning for New Technologies

I suspect that a second reason people respond differently to the prospect of technological revolution and political revolution is that we don't usually think of technological revolution as involving other people exercising power over us. People tend to react badly to conspirators and, more generally, to the thought that other people are making plans which will affect them without their knowledge. Yet, we tend not to think of technological change as resulting from plans that others have made without consulting us. Instead, we imagine that technology just "happens" [39].

However, as the scenario above suggests, there *is* planning involved in introducing new technologies. Many of the reports that have been commissioned into nanotechnology over the last decade are examples of precisely this — of governments taking conscious political action in relation to a new technology ([31], [41], [42], [52], [69]). Governments invest in some technologies and not others. They have industry, research, and telecommunication strategies. They pass laws requiring the use of some technologies

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[2]For further discussion of the role played by claims about the "revolutionary" nature of nanotechnology in debates about nanotechnology, see Sparrow [58]

[3]Note that according to this measure many political revolutions have equally failed to live up to the name.

and prohibiting the use of others. In all these ways and more, governments plan and shape our technological future.

Such planning also goes on in the "private" sphere. Large corporations such as Microsoft, Xerox, and IBM choose to research certain technologies, to bring certain technologies to market, and to abandon others. They establish research laboratories, research programs, and production facilities to bring their plans to fruition ([6, p. 221], [19, pp. 57-68]). Planning for technological "development" also goes on between corporations. Industry groups and conferences are organized to develop industry standards and to lobby governments to invest in the infrastructure and the regulations necessary for their preferred technologies to flourish [63]. The idea that technological development just "happens" is a myth.

That may be true, a critic might respond, but it is still the case that there is no one group in charge of developing nanotechnology and therefore no one group exercising power over us.

However, the absence of a single organized group controlling the nanotechnological revolution fails to distinguish this revolution from political revolutions. Most political revolutions are the result of widespread social movements that emerge in times of social crisis, without any central organization. Those few groups who are consciously fomenting revolution seldom make the revolution go entirely according to a single plan. Yet because those groups *are* making plans, they are likely to exercise more influence over the revolution than others not making plans for the revolution.

The number of actors involved in introducing technological change is actually quite small, especially when considered on a global scale. A relatively small and homogeneous group of people — scientists, engineers, entrepreneurs, and bureau-crats — are making decisions that will shape the development and application of nanotechnology [21], [67]. If it is true that nanotechnology will change the world then, as a group, these people clearly do have the power to transform our lives. We should be just as concerned about their identity and politics as we would those of any other revolutionary group.

Sense of Inevitability

Another reason people might not worry about technological revolution is that they feel that such change is — as the revolutionary in my hypothetical scenario insisted — inevitable ([12, p. 194], [23, pp. 187-188], [42], [64, pp. 12, 188]). We can't do anything about it, so why worry about it?

On the face of it, this is an odd response to reports of an imminent revolution. History is as full of political revolutions as it is of technological revolutions. Yet few people would, I think, respond to news of an imminent political revolution with a shrug and the observation that "revolution is inevitable."

Moreover, the supposed inevitability of technological change is much exaggerated. Most of human history has *not* consisted of wave after wave of unimpeded technological change. The current pace of technological change reflects existing social, political, and economic arrangements, which are the products of human choices [50, p. 1007]. Humanity could — and occasionally does — collectively turn away from particular technologies, as it has by-and-large from chemical and biological weapons, and — more recently — from reproductive human cloning [2], [23, pp. 188-189].

It is true that attempts to regulate technology often raise difficult collective action problems. Even if a community as a whole decides it does not want a particular technology, individuals or factions within the community may feel that it is in their interest to develop it. The first people to adopt a new technology often gain a competitive advantage over those who do not have access to it. Individuals may further reason that, "If we don't develop/use this technology someone else will — and then we will lose out" [17], [35, pp.114-117], [57, p. 147-148], [67, pp. 277-278]. If everyone follows this reasoning, the technology infiltrates the community. This may happen even if the entirely predictable result is that once the competitive advantage disappears nobody is any better off than before; indeed it may happen even where the result is that everyone is worse off than before! The collective action problems involved in regulating technology are especially acute when the community concerned is a global one, so that individuals have few ways of knowing whether others are abiding by the collective decision, and have reduced confidence in the community's capacity to enforce its decision [9].

However, collective action problems of this sort are the meat and potatoes of politics [28], [56]. If we stopped trying to exercise collective control over our destiny whenever it was difficult due to the existence of competing interests, we would soon have no social institutions at all. There are many situations where what it is individually rational and what is best for the group differ. The solution to collective action problems which relate to technology is the same as the solution to other collective action problems: empower the community to reshape the incentive structures of its members so that it is easier for individuals to trust that others will abide by the decision of the collective. This is the solution that governments and international bodies have adopted in several notable cases where they have set out to prohibit certain technologies including, for instance, chemical, biological, and nuclear weapons. If such regulation is difficult to achieve at an international level, this only draws attention to the

need for stronger institutions of democratic governance at a global level in order to make effective collective decisions possible.

It is untrue that as a society, or even as an international order of societies, we are necessarily unable to control the development and application of new technologies [23, pp. 188-189]; [37, pp. 167-205]. It may be *difficult* to do so, but these difficulties are similar to the difficulties facing communities and governments across a wide range of policy areas. Our passivity in the face of social change due to technological revolution is a form of "learned helplessness."

Optimism About "Progress"
Another possible explanation as to why we are not as apprehensive about technological as political revolutions is that most of us share a deep-seated culturally-ingrained belief in technological "progress" [25], [38, p. 17], [42, p. 8], [54], [68, p. 5]. As a consequence, we are inclined to view each new technology as a better technology and a society with better technology as a better society. In fact, how to assess the ultimate impact of any particular technology on human happiness and well-being is a difficult and controversial question. Putting this aside for the moment, it is clear that technological change produces losers as well as winners [13]. It is at the very least an open question whether or not the majority of ordinary citizens will be winners from a technology which is being shaped by some of the wealthiest and most powerful corporations in the world [21], [59], [67]. The idea that technological change will *automatically* make all of us, or even most of us, better off is naive.

Our culture's optimism about technology is also looking less and less justified in the face of the accelerating global environmental crisis [65]. Considering their environmental impacts, we might well have been better off if we had rejected, for

example, the technology of private motor vehicles and coal-fired power stations. The length of the period between the development of these technologies and the arrival of the consequences of their adoption has allowed our optimism to flourish unchecked by important realities. As the reality of global warming, in particular, intrudes upon our awareness, we may be forced to revise our belief that all technological change constitutes progress.

In any case, the fact that we ourselves judge that a particular technological change is for the better should not be enough to reconcile us to the prospect of such change where it is directed by the choices of others. Revolutionaries tend to believe that their revolutions will make everyone better off. Yet action to bring about a revolution on the basis of this optimism is justified only if it is legitimated by the consent of the majority of citizens.

Consumers and "Free Choice"
This brings us to the final possible explanation for our apparent calm in the face of the prospect of radical technological change: the belief that technological change is already an essentially democratic process. Because, as individuals, we have had the experience of embracing new technologies by buying the latest gadgets, it is easy to assume that new technologies only come into being as a result of demand from consumers, and that this makes the process a democratic one. Unfortunately, neither of these assumptions is true.

While the "free market" plays a crucial role in driving technological change, the desires of consumers play only a minor part in this process. As consumers, individuals express their preferences amongst the technologies made available to them rather than the full range of possible technologies. For the most part, then, consumer demand follows technological

change rather than drives it. Nor are all persons equal when it comes to those decisions which do influence the nature and direction of technological change. For instance, the decisions of an Apple marketing manager or engineer are vastly more important in determining the design of digital music players than the decisions of a consumer who buys an iPod. Most technological revolutions are shaped by the choices of producers, or by governments, rather than by the choices of consumers [43], [51, esp. pp. 9-23], [68, pp. 22-29]. The circumstances of unrestricted competition in which these decisions are made are often such that corporations and governments themselves feel that they have little choice but to develop and adopt new technologies. So important is the role played by competition in shaping these decisions that it is fair to say that the direction and pace of technological change today is largely driven by the economic order — capitalism — itself.

More importantly, even if we do wish to insist that technological trajectories ultimately reflect the choices of individuals, the circumstances in which individuals have an opportunity to express their desires in relation to a new technology matter. Democracy requires collective decision-making, which in turn requires public discussion and debate [10], [22], [27], [69, p. 40]. Collective decision-making, along with the possibility of establishing institutions to enact and enforce the decisions, is necessary in order to avoid the destructive effects of collective action problems of the sort discussed above [28], [56]. In the absence of the capacity to make a collective decision, the circumstances in which individuals make decisions structure the decisions rather than, as should be the case, the other way around. Democracy allows societies to

determine their own destiny even in circumstances where the interests of individuals conflict.

If the role of market forces was enough to render technological change democratic then we could rest easy in the faith that change will not happen unless "we" want it. However, as argued above, free markets and democracies are different things. The outcome of individual choices aggregated by the mechanism of the market will often be very different to that which we would have chosen through a democratic process.

Reconsidering Revolution

It seems then that none of the considerations I have surveyed here justify drawing a sharp distinction between change due to technology and change due to other political causes. At least two things follow from this conclusion for discussions of the social impact of nanotechnology.

First, we need to reconsider the appropriateness of the language of technological revolution when talking about nanotechnology. The development of new, improved technologies may have little impact on the fundamental nature of human lives. It may be that on a more sober evaluation of the likely impacts of nanotechnology we realize that they will be less dramatic than the quotations above suggest. This would mitigate — but not entirely eliminate — the need to consult the public about whether they wish to experience these impacts. Of course, it would also cast doubt on the urgency with which governments are pursuing nanotechnology and on the amount of funding being dedicated to nanotechnology research and development.

Second, if we do decide that the language of revolution is appropriate when talking about nanotechnology then we should acknowledge that this has significant implications. To the extent that it is true that nanotechnology will change the world, we should

be just as concerned about this prospect as we would be if it were an approaching political revolution of the more familiar sort.

Let us return to the scenario with which I started this paper. What would we demand if we learned that an unelected cabal was initiating a political revolution? It would not be unreasonable, I think, to demand that these revolutionaries be arrested. They should certainly be stopped from carrying out their revolution until their plans can be opened up to public scrutiny and, if necessary, put to a vote. What's more, this demand would hardly be controversial. It follows straightforwardly from the fact that an unelected group is threatening to wield power outside of the democratic process. If the duly elected government was unwilling to protect us from these self-appointed revolutionaries, we would properly question its legitimacy.

Thus, if we are on the verge of a nanotechnological revolution (as many nanotechnology researchers have declared), it follows similarly that those researchers should be prevented from radically transforming our world until we, as a society, have had the chance to consider whether we desire this transformation. Organizations already planning this revolution should be required to submit their plans to the public for scrutiny and approval. If these measures sound like an infringement of researchers' liberty then we would do well to keep in mind the right of the rest of the population not to be subjected to a revolution without their consent. If we feel it will be difficult to prevent a nanotechnological revolution because of the difficulties involved in regulating technology, then we must strengthen the institutions of democratic control necessary to accomplish such regulation [2], [36], [38], [57, pp. 145-150], [67]. The alternative is to give over control of our future to unelected techno-revolutionaries.

Pausing at crucial points to allow for public reflection

will necessarily slow down the development of nanotechnology. However, if nanotechnology really will be as wonderful as its proponents suggest, then the public will presumably recognize its advantages and eventually embrace the nanotechnological revolution. A short delay seems a small price to pay to ensure that the consequences of nanotechnology are indeed beneficial and that these benefits are thought to be worth whatever other social impacts occur in the their pursuit. More importantly, it is a price we have to pay if we wish to continue to claim to be a democratic society while at the same time allowing that our society will be transformed by the introduction of nanotechnology.

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